The author proceeds to trace the connexions of these cavities with the lymphatic vessels in the neighbourhood, and with one another: and it appears from his researches, that the lymph of the hinder extremities, as well as that of the posterior part of the abdomen, is conveyed by means of these hearts into the trunk of the crural veins. He also gives a description of the posterior part of the venous system of the frog, noticing particularly the large transverse anastomosis between the sciatic and the crural veins, which joins the anterior median vein of the abdomen, and conducts the blood partly into the vena portæ, and partly into the renal veins.

Professor Müller has likewise discovered two anterior lymphatic hearts in the frog; a discovery to which he was led by some observations of Dr. Marshall Hall, who stated that he had seen in that animal an artery pulsate after the removal of the heart. These anterior lymphatic hearts lie on each side upon the great transverse process of the third vertebra, immediately under the posterior end of the scapula, and they are nearly as large as the posterior hearts. They receive the lymph of the anterior parts of the body, and probably also that of the intestinal canal, in order to transmit it into contiguous veins, which pour their contents into the jugular vein. The author has discovered similar organs in the toad, the salamander, and the green lizard; and is of opinion that they exist in all the amphibia.

The following announcement was made from the Chair:—

"His Royal Highness the President has received from Professor Gauss the abstract of a paper read by him at the meeting of the Royal Society at Göttingen, on the 15th of December last, entitled '*Intensitas vis magneticæ terrestris ad mensuram absolutam revocata.*' Mr. Gauss's views possessing considerable interest, His Royal Highness is desirous that they should be made known to the Fellows of the Royal Society; but as the original paper will not be printed for many months, and the abstract which appeared in the *Göttingische gelehrte Anzeigen* is in a language not generally understood in this country, His Royal Highness has requested your Foreign Secretary to translate it; and I am commanded to desire your Secretary to read the same to the present meeting.

"In deviating thus far from the usual routine of the business of the Royal Society, His Royal Highness is actuated by a wish to promote the reciprocal and early communication of new and important discoveries and views in science, between our own and the other Societies of Europe, devoted, like this, to '*the improvement of natural knowledge.*'

"Communications of this nature, however, cannot of course be admitted into your Transactions; but the publication, from time to time, of your Proceedings, affords a happy means of giving them general circulation; and thus the rapid propagation of much valuable information will be effected, which otherwise, if not absolutely lost to us, would, at least, long remain unknown to the British scientific public."

The following is the abstract of Professor Gauss's Memoir :—

Of the three elements which determine the manifestation of terrestrial magnetism in a given place, viz. Declination, Inclination, and Intensity, the first soonest engaged the attention of philosophers, the second much later, and the third has only at a very recent period become an object of investigation and experiment. This progressive interest is chiefly to be accounted for by the circumstance, that while the variation of the compass offered the greatest interest, as applied to the purposes of navigation and geodesic operations, the dip was looked upon as more nearly allied to it than was the intensity of terrestrial magnetism. To the natural philosopher, those three elements are absolutely of the same import, inasmuch as our knowledge of the general system of terrestrial magnetism will ever remain imperfect, until an equal share of attention has been bestowed on its separate branches.

For the first light thrown upon this subject we are indebted to the Baron Humboldt, whose attention was particularly directed to it during all his travels, and who has furnished a considerable series of observations, from which the gradual increase of this intensity, from the magnetic equator of the earth towards the magnetic poles, has been deduced. Many observers have since followed the footsteps of that great naturalist; and almost every part of the world to which, in recent times, travellers have penetrated, has furnished its quota of materials, from which already Hansteen (to whom this branch of philosophical inquiry is under great obligation) has been enabled to attempt the construction of an iso-dynamical chart.

The mode adopted in all these observations consists in disturbing the equilibrium of one and the same magnetic needle in places the comparative intensity at which is to be determined, and in exactly measuring the duration of its oscillations. This duration is indeed, *cæteris paribus*, dependent on the magnitude of the arc; but in such a manner, that however small the arc becomes, it still approaches a determined limit, loosely called the duration, and to which, the arc of oscillation being known, the really observed duration may easily be reduced. The intensity of terrestrial magnetism is thus inversely proportional to the square of the duration of oscillation of the same needle, or directly so to the square of the number of oscillations in a given time; and the result relates to the whole force, or to the horizontal portion of it, according as the needle has been caused to vibrate, in the plane of the magnetic meridian, round a horizontal axis, or, in a horizontal plane, round a vertical axis.

It is evident that the admissibility of this method entirely rests on the assumption of the unchanged magnetic state of the needle employed. If a properly-magnetized and carefully-preserved needle of good hardened steel be made use of for the experiments, and these do not take up too long a space of time, the danger to be apprehended from such alteration may not, indeed, be considerable; and the observer may rest the more satisfied in this respect, if, on returning to the first place, he find the time of the vibration to be the same; but experience teaches ns that this result cannot by any means be calculated

upon ; neither can it be denied, that in resorting to such a proof we are only reasoning in a circle. It was known indeed, long ago, that both the declination and inclination in the same place are far from being invariable; that both of them, in the course of time, undergo very considerable progressive variations, independently of those periodical ones by which the nicety of observation is affected in different seasons and parts of the day. It is, therefore, no matter of doubt that the intensity of terrestrial magnetism must likewise be subject to them ; indeed, the periodical diurnal variations are clearly perceptible in delicate observations. Hence, even if, after a considerable lapse of time, the same time of vibration is again observable in a given place, we are not, on that account, warranted in ascribing this circumstance to anything but a casual compensation of the variations which the intensity of the magnetism of the earth in that place, and the magnetic state of the needle itself, may have experienced during that interval. But even allowing the certainty of the comparative method to be only diminished to a certain degree, not entirely annulled, provided too long a space of time do not intervene, that mode, at all events, becomes entirely useless in cases where it is required to ascertain what changes the intensity of terrestrial magnetic force undergoes in a given place during a very long interval. This question, of considerable interest in a scientific point of view, must, therefore, remain unanswered until the merely comparative method shall be superseded by one which reduces the intensity of terrestrial magnetism to unities perfectly determined and manifest, and entirely independent of the individual nature of the needles employed in the experiments.

It is not difficult to lay down the theoretical principles on which such an independent method is to be founded. The time of oscillation of a given needle depends on three quantities ; namely, the intensity of the terrestrial magnetism, the static momentum of the free magnetism in the needle, and the momentum of the inertia of this needle. The last of them may readily be ascertained by suitable methods ; and thus, from the observed duration of the oscillation, is deduced, not the quantity of the intensity of the terrestrial magnetism, but the product of this quantity into the static momentum of the free magnetism in the needle. But it is impossible to separate these two factors from one another, unless observations of quite a different kind be superadded, that involve a different combination of them ; and this end is attained by the use of a second needle, which, in order to ascertain the ratio of these forces, is subjected both to the influence of the magnetism of the earth and to that of the first needle. These two effects do, indeed, partly depend on the magnetic state of the second needle; but, by suitably conducting the experiments, the observer may eliminate that state, inasmuch as the *ratio* of both forces becomes the more independent of it, the greater the distance of the two needles from one another is assumed. Here, however, it is obviously necessary, at the same time, to consider the position relative to the magnetic meridian, of the magnetic axes of both needles, and of that of the straight line connecting their centres, as also the magnetic state of the first needle; all which cannot be subjected to

computation unless we know the law of the force exerted on each other by two elements of free magnetism, or, in other words, with which, according as they are of the same or different denominations, they repel or attract each other. Tobias Mayer had already conjectured this law to be the same with that of general gravitation, i. e. that the force is in the inverse ratio of the square of the distance. Coulomb and Hansteen have endeavoured experimentally to confirm this conjecture; and the fact is now completely established by the experiments detailed in Professor Gauss's forthcoming memoir. This law, however, only relates to the elementary effect; for the computation of the total effect of a magnetic body on another, as soon as the nature of the distribution of free magnetism in these bodies is accurately known, becomes a problem purely mathematical, and consequently remains dependent on their casual individual nature; but the greater the distance, the less the influence of this individuality becomes; and if the distance be very great, we may, *cæteris paribus*, assume (as indeed follows from the above principle,) the total effect to be inversely proportional to the cube of the distance. The product of this cube into the fraction which expresses the ratio of the effect of the first needle, and of the terrestrial magnetism on the second needle, will therefore, as the distances continually increase, tend to a determined limit. A proper combination of observations at several judiciously selected distances will, being mathematically treated, make us acquainted with that limit, from which may be deduced the *ratio* of those two quantities the product of which was derived from the observed times of vibration. The combination of both results will then obviously give those two quantities themselves.

The experiments for comparing the effects of the magnetism of the earth, and of the first needle on the second, suspended by a thread, may be conducted in two different ways; inasmuch as the latter may be observed either in a state of motion or of rest. The former is best effected by placing the first needle in the magnetic meridian of the second, whereby the time of a vibration of the latter is either increased or diminished, according as poles of the same or of different names are opposed to each other. The comparison of the time of vibration thus changed, with that occasioned by terrestrial magnetism alone, or rather, the comparison of an increased with a diminished one (under opposite directions of the first needle), will then readily lead to the ratio sought. The second mode is that of placing the first needle in such a manner that the direction of its influence on the second makes an angle with the magnetic terrestrial meridian; when the angle of deviation from the meridian, in a state of equilibrium, will equally lead to the knowledge of the ratio sought. And here, too, it is more advantageous to compare with each other two opposite deviations, under opposite positions of the first needle. The most advantageous position of this needle is along a straight line drawn through the middle of the second and perpendicular to the magnetic meridian. The first mode agrees upon the whole with that proposed some years ago by Poisson; but the experiments, as far as we have any record of them, made by some natural philosophers with a view to apply that mode, have either

entirely failed, or their results can at best be considered only as imperfect approximations.

Professor Gauss, who has made frequent trials of both those modes of proceeding, is satisfied that the second is, on many accounts, far preferable to the first.

The real difficulty consists in this, that other elements depending on the individual nature of the needles, enter, as well as the value of the limit, into the influences observed. That effect is represented by a series which proceeds by the negative powers of the distance, beginning from the third; where, however, the following terms become more considerable as the distance is smaller. Now those following terms are to be eliminated by means of several observations; but a slight acquaintance with the theory of elimination easily convinces us that unavoidable errors of observation will never fail to endanger the exactness of the results, as the number of co-efficients to be eliminated is greater; so that their number need not be very considerable to render the results of computation entirely useless. No precision, therefore, in the results can be expected, unless such considerable distances are employed as will make the series rapidly converge, and a few terms of it suffice. But in this case the effects themselves are too small to be determined with exactness by our present means of observation; and thus the ill success of the experiments hitherto made is readily explained.

However easy, therefore, in theory the methods of reducing the intensity of terrestrial magnetism to absolute unities may appear, yet their application will ever remain precarious until magnetic observations have attained to a much higher degree of precision than they have hitherto possessed. It is with this view that Professor Gauss has followed up several ideas long ago entertained by him relative to the improvement of our means of observing; confidently expecting that magnetic observations will, ere long, be carried to a degree of perfection nearly, if not altogether, equal to that of the most delicate astronomical observations. The expectation has been answered by the result. Two apparatus fitted up in the observatory of Göttingen, and which have been employed for making the observations, of which several are given in his memoir, leave nothing to desire but a suitable locality completely secured from the influence of iron and currents of air.

The following short abstract from the detailed description of the two apparatus and their effect, given in the memoir itself, will no doubt be acceptable to naturalists interested in this kind of research.

Professor Gauss has generally employed needles (if prismatic bars of such strength may be designated by that name) of nearly a foot in length, weighing each about one pound. They are suspended by an untwisted thread of $2\frac{1}{2}$ feet in length, composed of thirty-two threads of raw silk, and thus able to carry even double that weight without breaking. The upper end of the thread is tortile, and the degree of torsion is measured by means of a divided circle. To the south or the north end of the needle (according as the locality renders either the one or the other more convenient), a plane mirror is fixed, the sur-

face of which, by means of two adjusting screws, may be placed perpendicular to the axis of the needle; but scrupulous attention need not be paid to this adjustment, as any deviation may most exactly be measured by the observations themselves, and taken into account as errors in collimation. The needle thus balanced is enclosed in a wooden cylindrical box, which, besides the small aperture in the lid for the passage of the thread, has a larger one in the side, which is rather higher and wider than the mirror already mentioned.

Opposite to the mirror, a theodolite is placed, the vertical axis of which is in the same magnetic meridian with the thread of suspension, and at a distance from it of about sixteen Parisian feet. The optical axis of the telescope is placed rather higher than the needle, and inclined in the vertical plane of the magnetic meridian, so as to be directed towards the centre of the mirror on the needle.

To the stand of the theodolite is fixed a horizontal scale of four feet in length, divided into single millimetres: it makes a right angle with the magnetic meridian. That point of the scale which is situated in the same vertical plane with the optical axis of the telescope, and which, for the sake of brevity, may be denominated the zero point, is marked out by a fine thread of gold depending from the middle of the object-glass, and charged with a weight. The scale is fixed at such a height that the image of a portion of it is seen in the mirror through the telescope, the eye-glass of which is adjusted accordingly. At the opposite side from the needle, in the same vertical plane, and at a distance from the telescope equal to that of the image, a mark is fixed, serving every instant to ascertain the unchanged position of the theodolite.

It is obvious, that if all these conditions be fulfilled, the image of the zero point on the scale will appear exactly on the optical axis of the telescope, and that, so far as an object of known azimuth is visible at the place of the theodolite, we may, by means of this instrument, immediately find the absolute magnetic declination. If, on the other hand, those conditions are only partially fulfilled, then, generally speaking, the image, not of the zero point, but that of another point of the scale, will appear on the optical axis; and if the horizontal distance of the scale from the mirror have been measured with exactness, it will be easy to reduce the amount of the divisions of the scale to the corresponding angle, and thus to correct the result first obtained. By turning the needle in the stirrup (so that the upper surface becomes the lower), the amount of the error of collimation of the mirror may be ascertained with great ease and precision. In both the apparatus, one part or division of the scale is equal to nearly twenty-two seconds; an interval which even the least practised eye may easily subdivide into ten parts.

By this mode of operating, therefore, the direction of the needle and its variations are determined with the greatest possible precision. It is by no means necessary always to wait till it is at rest; as the two elongations to the right and the left may be observed with great accuracy, and their combination, properly managed, will indicate the corresponding point of rest with equal precision. During the antemeri-

dional hours, when the daily variation is most rapid, this may be followed almost from one minute of time to the other.

Of equal importance is this mode of proceeding for observing the duration of the vibrations. The passage of the vertical thread in the telescope before a fixed point of the scale (properly speaking, the reverse is the case), may, even if the whole deviation only amount to a few minutes, be observed with such a degree of precision as never to leave any uncertainty amounting to the tenth of a second in time. The considerable duration of a vibration (about 14 seconds in the most intensely magnetized needles), and the slow degrees by which the arc decreases, are productive of other important advantages: only a few vibrations are required to enable us to determine the time of one vibration with such accuracy, that, though the needle be left to itself for one or even several hours, no doubt will remain on the mind of the observer as to the number of oscillations performed during the interval of his absence. We may commence with vibrations so small (such, for instance, as those with which we generally leave off,) that the reduction to infinitely small vibrations becomes almost imperceptible; and yet, after an interval of six and more hours, the vibrations are still found sufficiently great to admit of having their beginnings observed with all requisite precision.

In cases where anomalies still appear in the observations (which, however will prove so trifling, that with the common means they would have been altogether imperceptible,) they are solely to be ascribed to the current of air which, in the locality where the experiments were made, could not be altogether avoided. To remedy this inconvenience the aperture of the box might be closed by a plane glass; but none perfectly true was within the author's reach, neither could it have been made use of without an inconvenient loss of light.

To the enumerated advantages of this method another may be added, which is, that the observer constantly remains at a great distance from the needle, while in the old mode of proceeding his proximity to it was unavoidable; so that, even if enclosed in a glazed case, it was exposed to the disturbing influence which might be exerted upon it by the warmth of the body, or that of the lamp, by the iron or even the brass which the experimenter might happen to carry about him.

The advantages of stout heavy needles over those of diminutive size, which have been made use of for most magnetical observations, particularly those relating to the time of vibration, are dwelt upon by Professor Gauss; he has since successfully employed one weighing upwards of two pounds, and expresses his conviction, that if needles of from four to six pounds in weight were used, on which slight currents of air would cease to exert any perceptible influence, magnetic observations might attain an exactness and precision unsurpassed by the most delicate astronomical observations. Much stronger threads would indeed be required for suspension, the torsion of which would produce greater reaction; but whatever the strength of the thread may be, the force of torsion must always, and may without any difficulty, be taken into account with the greatest exactness.

The two apparatus may likewise be made use of for another purpose, which, though not immediately connected with the principal subject of the memoir, may still be adverted to in this place. They are the most sensible and convenient galvanometers both for the strongest and weakest energies of the galvanic current. To measure the strongest, it is only required to bring the conducting wire single, and at a considerable distance (at least several feet), into the magnetic meridian below or above the needle; for very weak energies a multiplier is wound round the box containing the needle. Some of the experiments were made with a multiplier of 68 circumvolutions, producing a length of wire equal to 300 feet. No pair of large plates is requisite: a pair of small buttons, or even simply the ends of two different metallic wires dipped in acidulated water, produce a current indicated by the movement of the image along many hundred parts of the scale; but on using a pair of plates of very moderate dimensions, the image of the whole scale, as soon as the circuit is completed, is seen rapidly to dart through the field of vision of the telescope. It is obvious that by this method the measurement of galvanic forces may be conducted with a degree of ease and precision unattainable by the hitherto employed laborious modes by means of observed times of vibration; and it is literally true that by it we are enabled to follow from second to second the gradual decrease of the intensity of a galvanic current, which, it is well known, is more rapid in the beginning. If, in addition, instead of the single, a double (astatic) needle is used, no degree of electro-magnetic energy will be found too small to admit of being still measured with the utmost precision. Here, therefore, a wide field is opened to the naturalist for most interesting investigation.

Not a small portion of this unpublished memoir of Prof. Gauss is taken up by the developement of the mathematical theory; and also by various methods peculiar to the author, such as the determination of the momentum of inertia of the vibrating needle, independently of the assumption of a regular figure; by his experiments with a view to establish the above-mentioned fundamental law for the magnetic effects; and, finally, by the details of the experiments to determine the value of the intensity of terrestrial magnetism, of which last the following may be given as the results, as far as they relate to the intensity of the horizontal part of that force.

I.	May 21	1·7820
II.	May 24	1·7694
III.	June 4	1·7713
IV.	June 24—28 ..	1·7625
V.	July 23, 24 ..	1·7826
VI.	July 25, 26 ..	1·7845
VII.	Sept. 9	1·7764
VIII.	Sept. 18	1·7821
IX.	Sept. 27	1·7965
X.	Oct. 15	1·7860

For unities, the millimetre, the milligramme, and the second in time

have been adopted. The manner in which the measurement of the intensity has been determined by them cannot here be specified : the numbers, however, remain the same, provided the unity of space, and that of weight (properly speaking, unity of masses), are changed in the same proportion. These experiments vary partly with regard to the greater or less degree of care with which they were conducted, partly with regard to the places in which they were made, and to the needles employed.

The experiments VII, VIII, IX, were in every respect performed with all the precision which the apparatus in the present state admits of, and the distances were measured with microscopic exactness. In experiments IV, V, VI, X, some operations have been performed with rather less care; and the three first experiments are still less perfect in this respect.

The needles employed in the first eight experiments were not indeed the same, but they were nearly alike in size and weight (the latter between 400 and 440 grammes); the principal needle in experiment X. weighs 1062 grammes; experiment IX. on the other hand is made, with a much smaller needle (weight 55 grammes), merely for the sake of ascertaining the degree of precision, which, all other precautionary means being alike, may be attained in using a needle of such small dimensions : the result of this experiment is therefore much less to be depended upon.

Experiments VII. to X. were made in one and the same place in the observatory; the preceding ones in other places in the same observatory, and in apartments of the author's dwelling-house. No perfectly pure results therefore could be derived from these latter experiments, inasmuch as the iron in those localities, and particularly in the observatory, becoming itself magnetic by the magnetism of the earth, would necessarily react upon the needle, and confound its influence with that of the terrestrial magnetism. Such places, indeed, were uniformly chosen in which neither fixed nor moveable masses of iron were near; nevertheless, even the more distant ones may not have been altogether without their effect upon the operations. However, on casting a look over the different results, it appears probable, that in no one of those localities, the modification of the terrestrial magnetism produced by extraneous influence exceeds the hundredth part of the whole. But results commensurate to the precision belonging to this mode can only be expected in a locality entirely free from the influence of iron.

In order to obtain the intensity of the *whole* force of the terrestrial magnetism, the numbers found are to be multiplied by the secant of the inclination. Mr. Gauss intends at a future period also to treat this element according to peculiar methods; in the mean time he merely mentions that on June the 23rd he has found 68° 22′ 52″ with the inclinatorium of the University collection of instruments,—a result which, as the observation was made in the observatory, and therefore not without the reach of local interference, may possibly require to be rectified by other observations.